Space Cloud: From a Distributed On-board Computer to a Federated System-of–Systems in Space

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Simulation and Software Technology

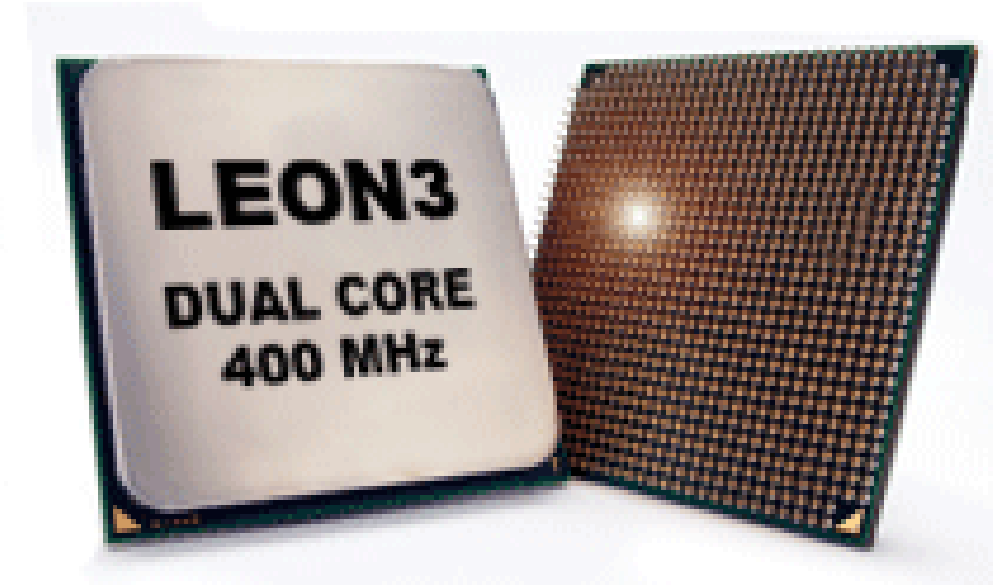
Software for Space Systems and Interactive Visualization

Federated Satellite Systems
Workshop 14th Oct 2014

Challenges in the area of data processing on-board spacecraft

Missing On-board Computing Power

- Number of space-qualified processors and FPGAs is low
- Increasing requirements for more computing power in the areas:
  - Optical Navigation – Example: ATON
  - Earth observations – Example: Tandem-X / TerraSAR-X
  - Robotics – Explorative Swarm
  - …

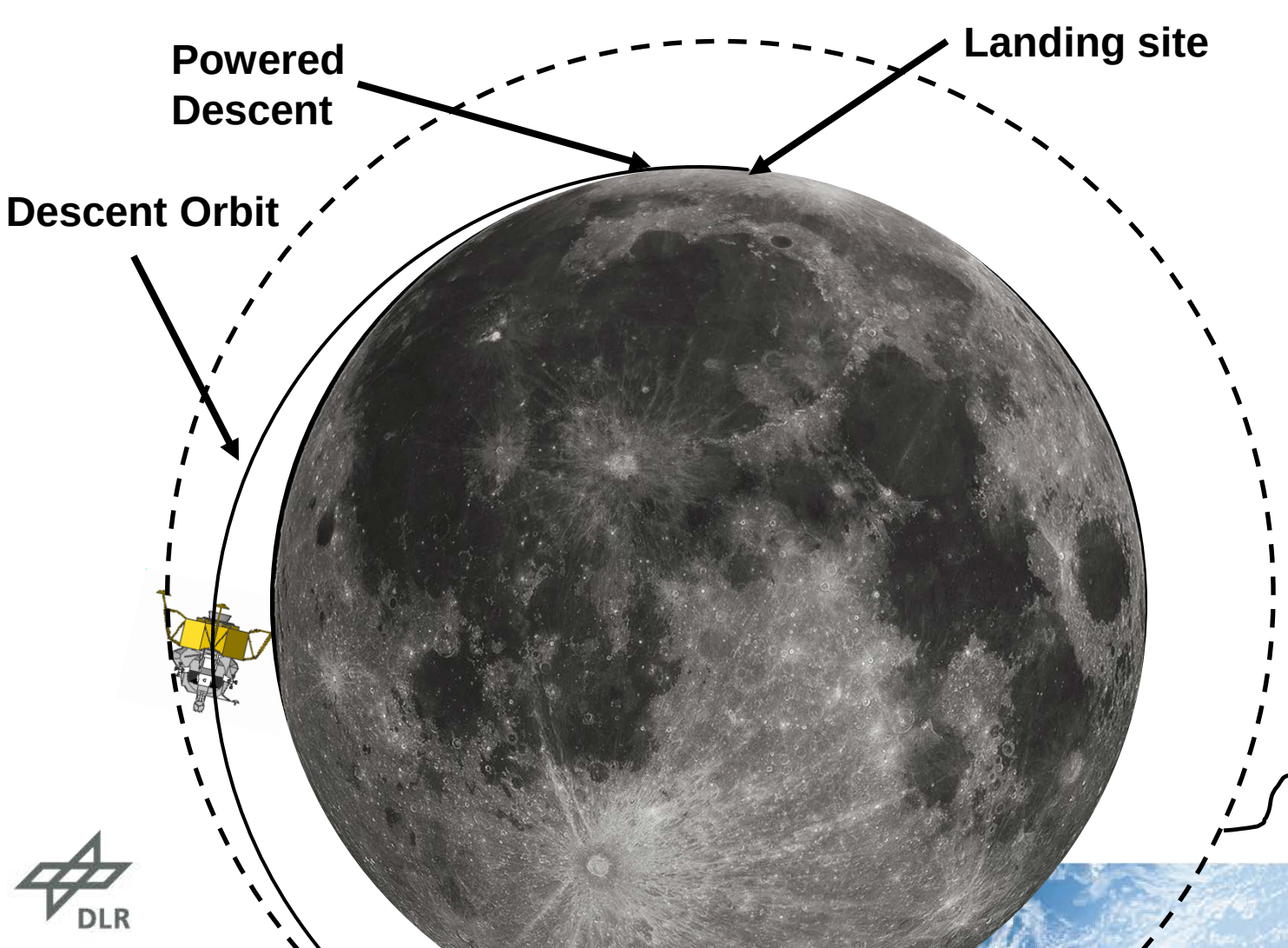


Redundancy Concepts Often Limited to Subsystems

- Each computing unit has usually its dedicated redundant counterpart
- Standby systems can not take over tasks of computers in other subsystems

Autonomous Terrain-based Optical Navigation for Landers (ATON)

Goal: Bring Optical navigation for autonomous landing on celestial bodies to TRL 4-6



Sensors

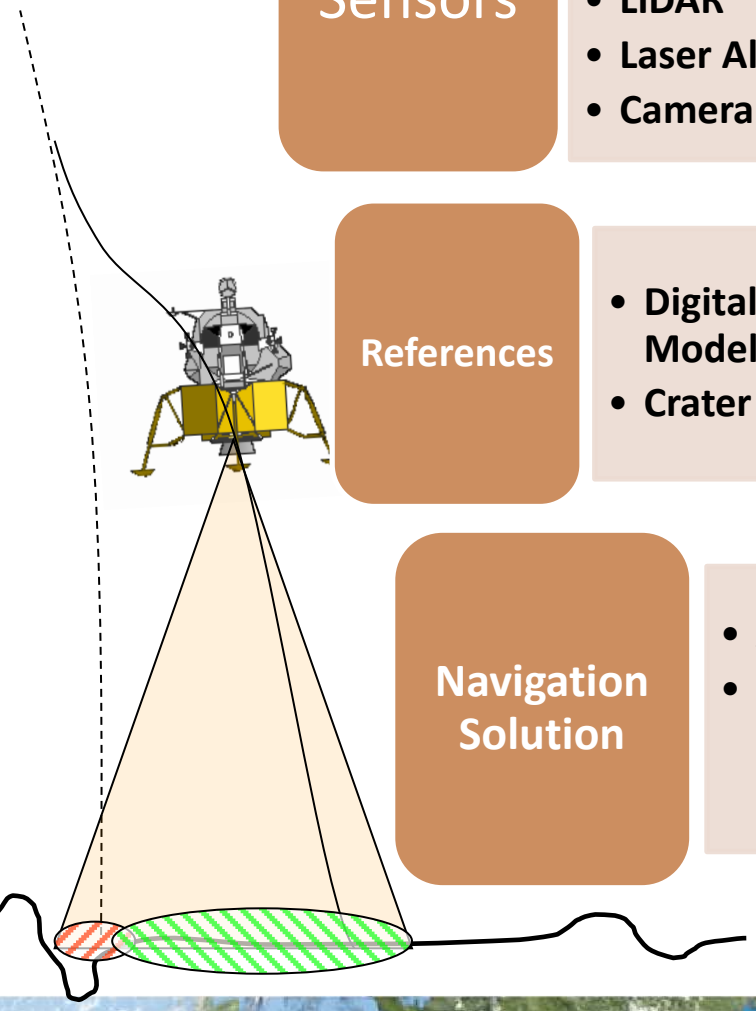
- IMU
- Star Tracker
- LIDAR
- Laser Altimeter
- Camera

References

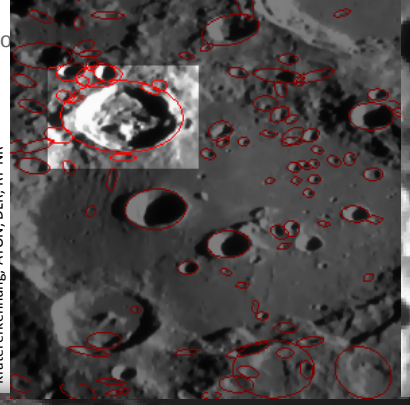
- Digital Elevation Model (DEM)
- Crater Catalogue

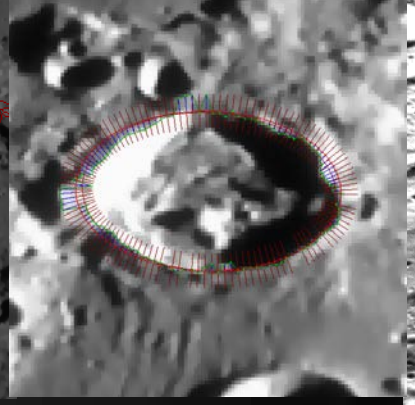
Navigation Solution

- At all times
- Different sensors active

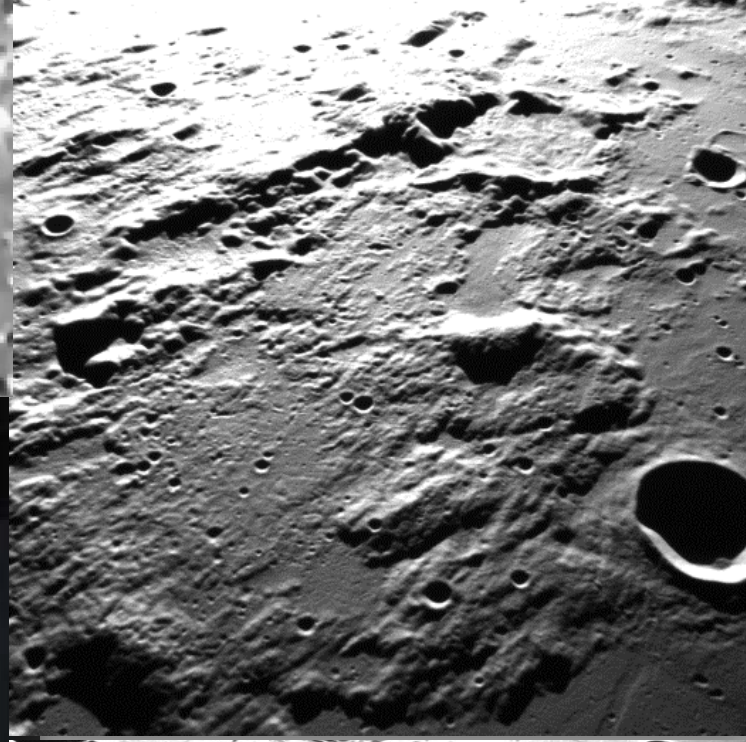


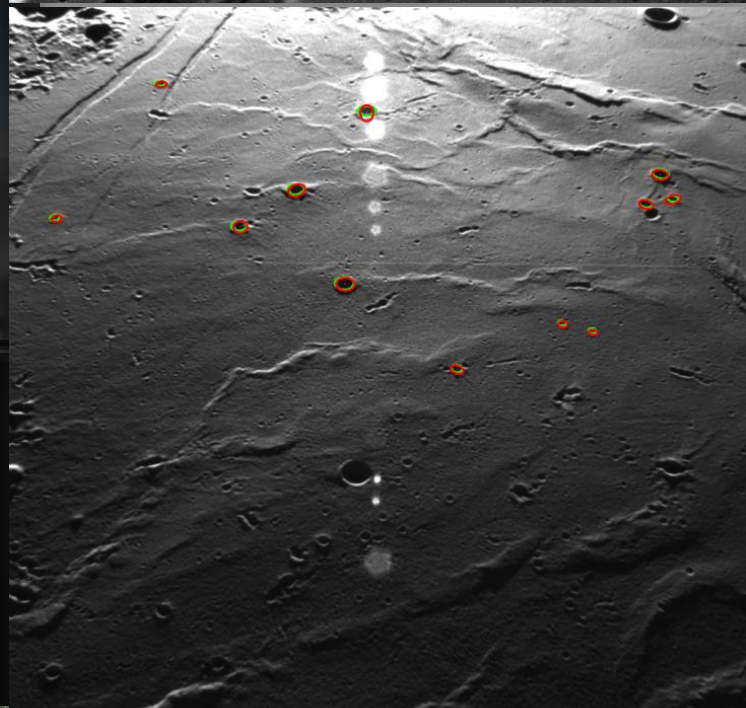
ATON continued





Kratererkennung, ATON, DLR, RY-NR





Software Tasks

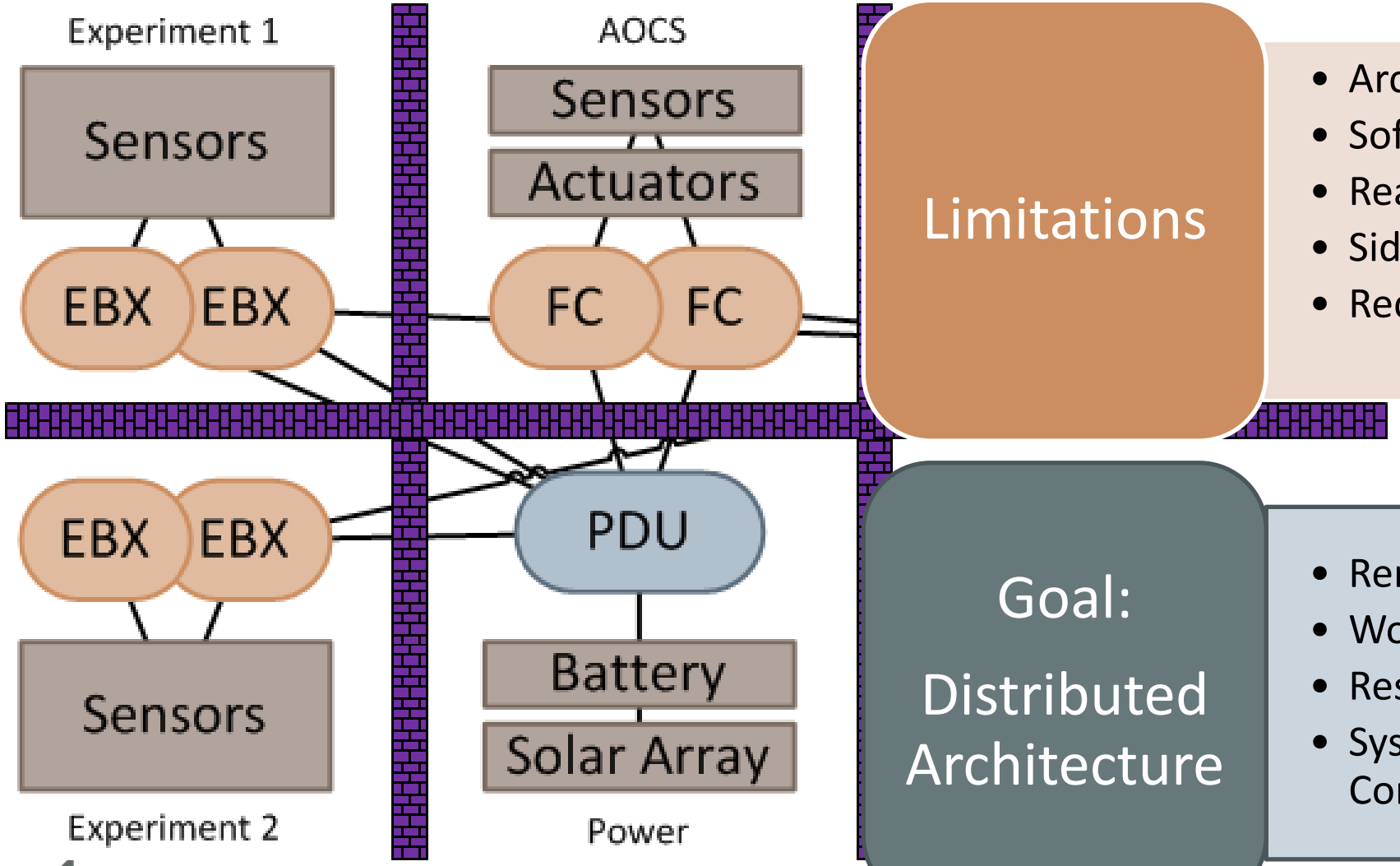
- Crater Detection
- Epipolar Geometry --> Stereo Matching --> 3D Matching
- Feature Tracking
- Landing Site Evaluation
- Navigation Filter

High demands on computing power

- Parallel tasks (CPU, FPGA)
- Short execution time (~ 1 h)

Images: DLR Institute for Space Systems

Subsystem Centric Design vs. Distributed Architecture



Limitations

- Architectures
- Software
- Real-time requirements
- Side effects
- Redundancy / High dead mass

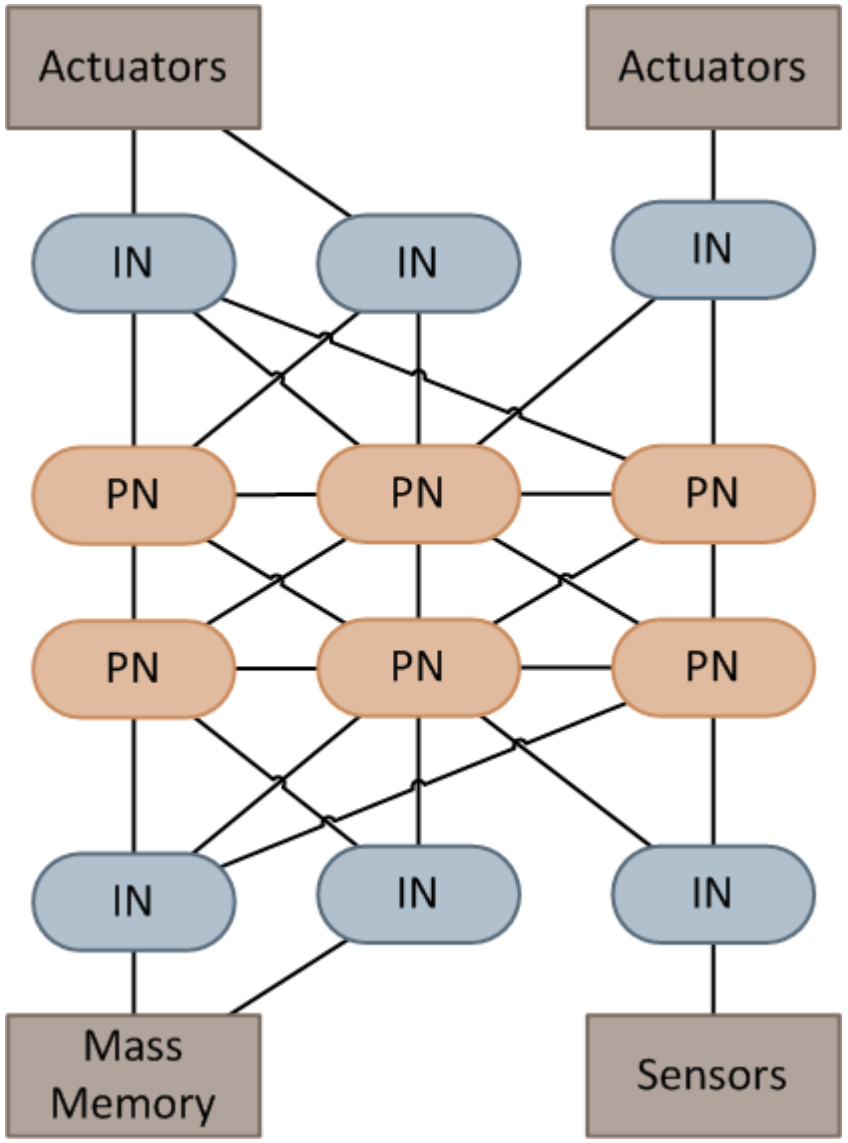
Goal:

Distributed Architecture

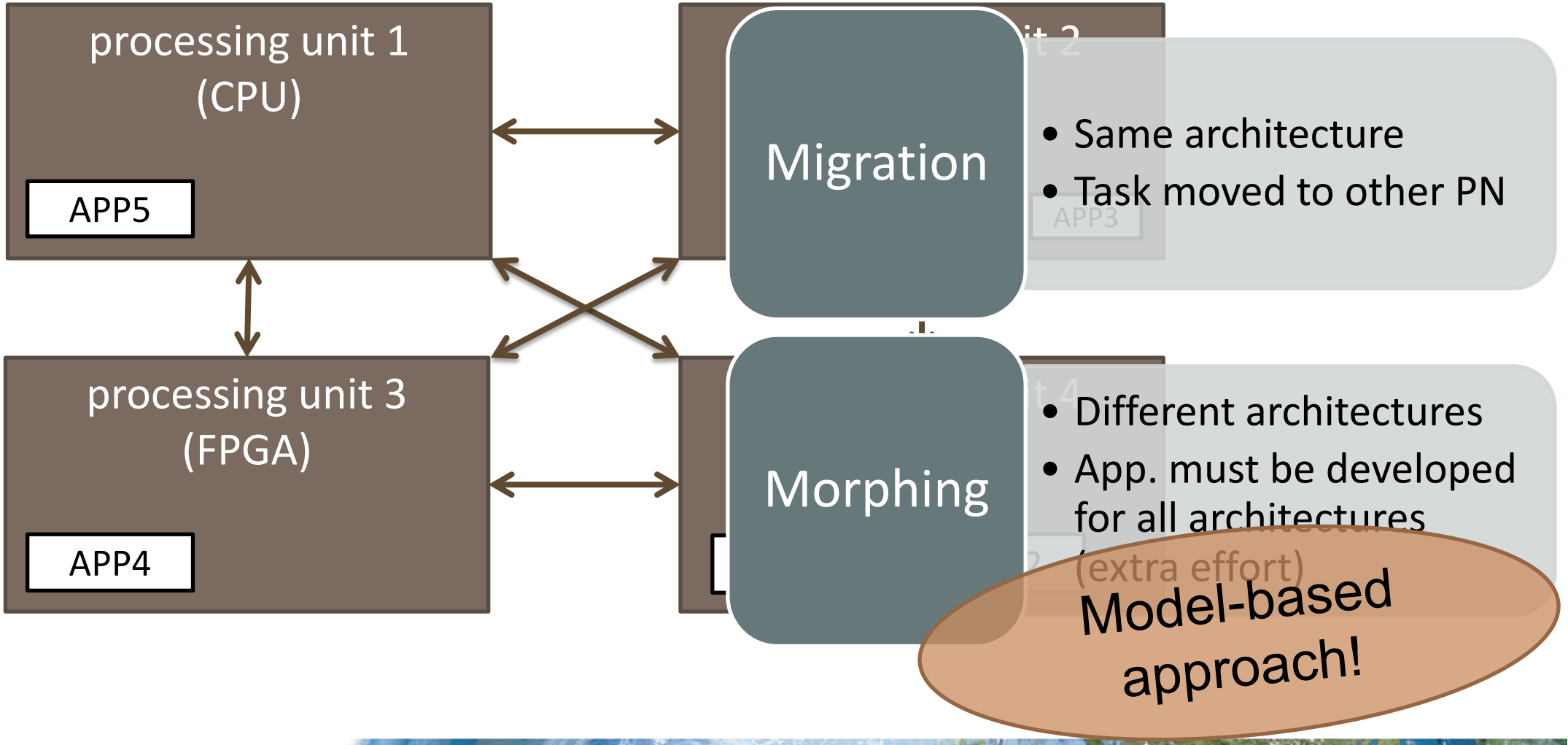
- Remove the walls!
- Workload balancing
- Resource sharing
- Systems Thinking for On-board Computers

DLR Research Activity
On-Board Computer – Next Generation (OBC-NG)

Resource Utilization	• Using all available computing resources
Redundancy	• Migration of applications across subsystems
Reconfiguration	• Software and hardware reconfiguration for different mission phases and error mitigation
Cost reduction	• Evaluation of Commercial Off-The-Shelf (COTS) Equipment

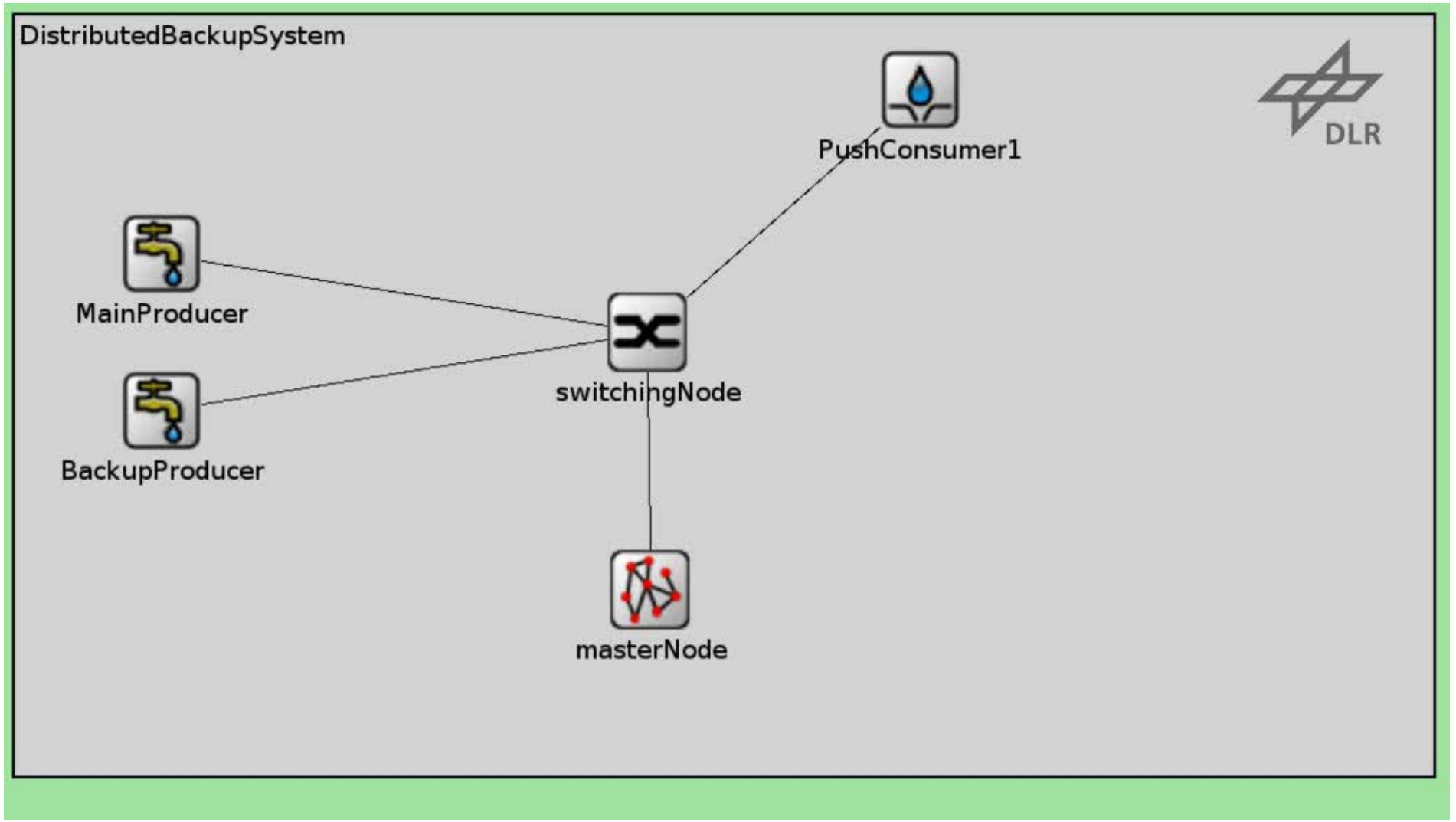


Reconfiguration – Task Migration / Morphing



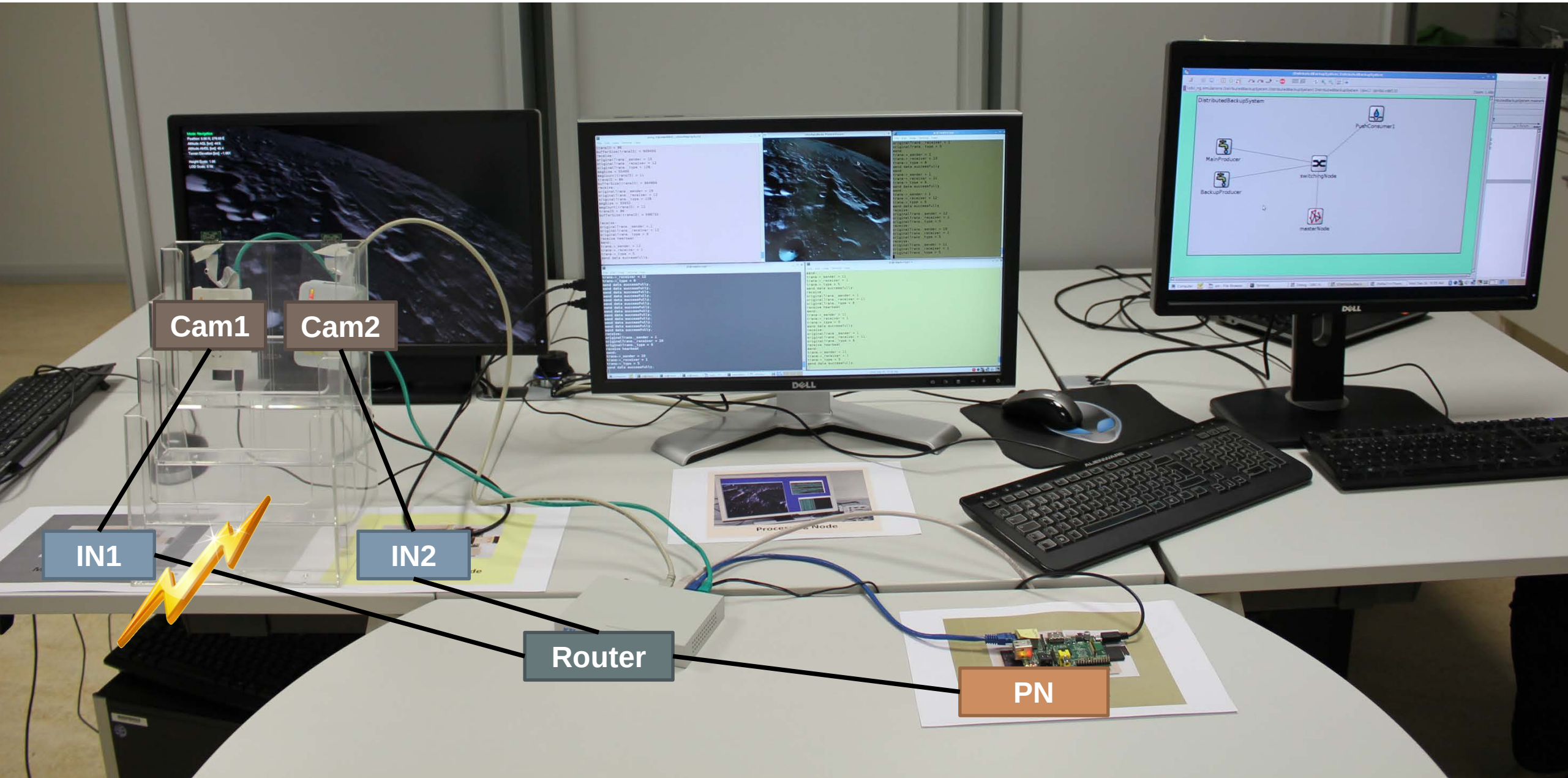
OMNeT++

Reconfiguration – Network Simulation



DLR

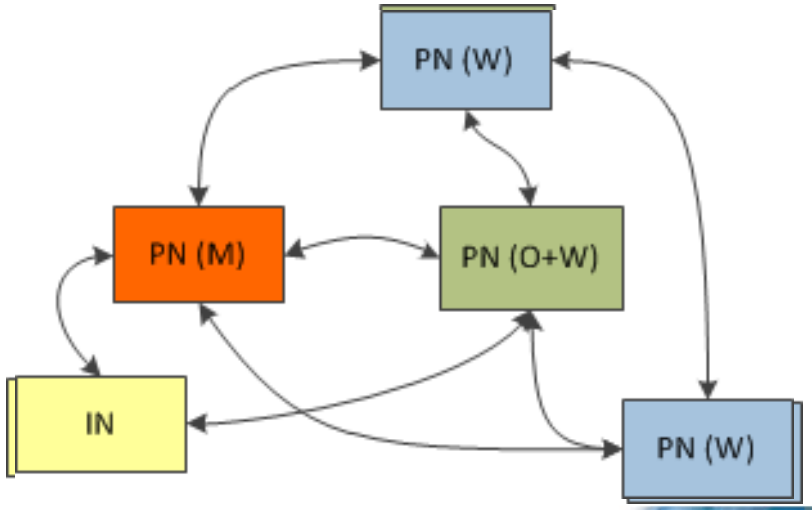
Demonstrator using Optical Navigation



How should the system reconfigure…?

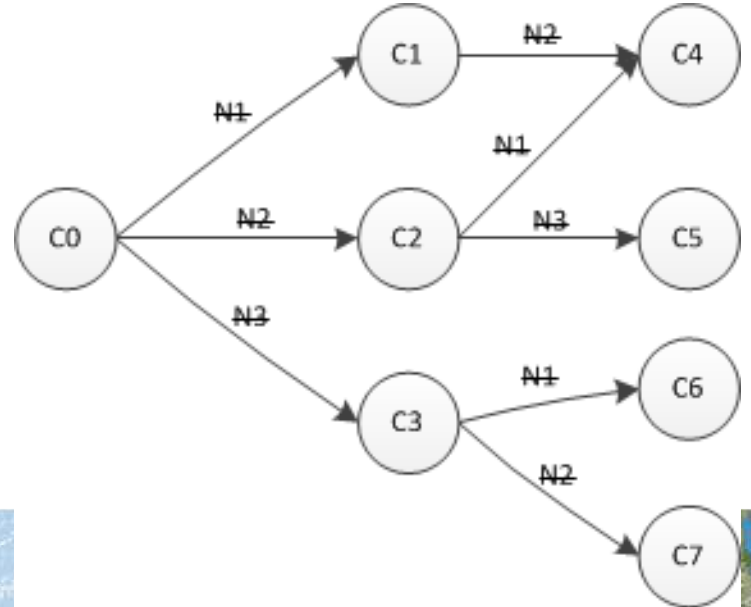
Planned

- Switching mission phases
- Cruise -> Land -> Explore
- Initiated by ground control
- Mission timeline



Automatic

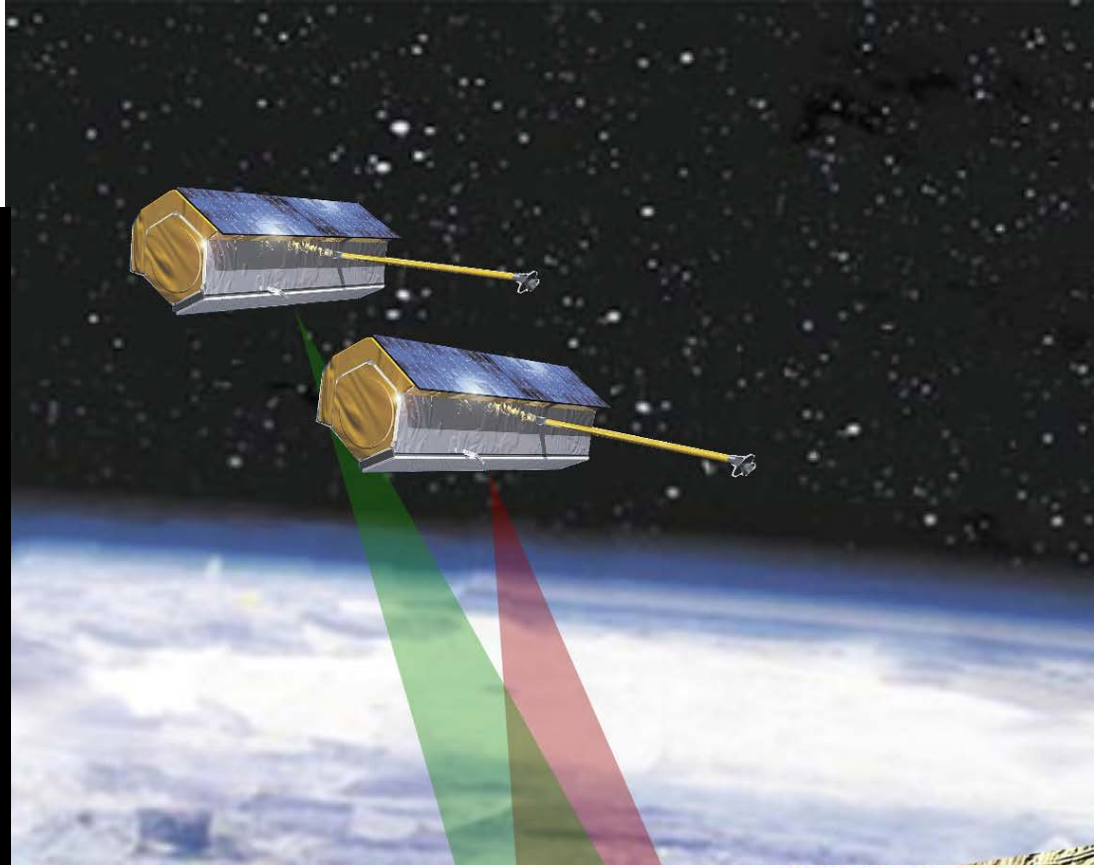
- Error Mitigation
- Initiated by Master after failure detection
- No adaptive reconfigurations
- Precalculated decision graph to mitigate node failures

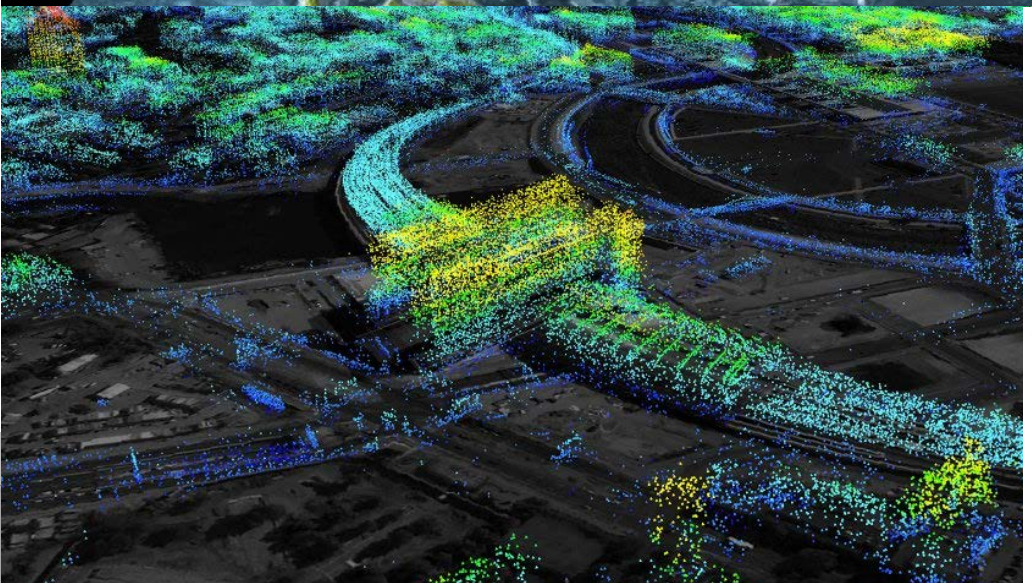


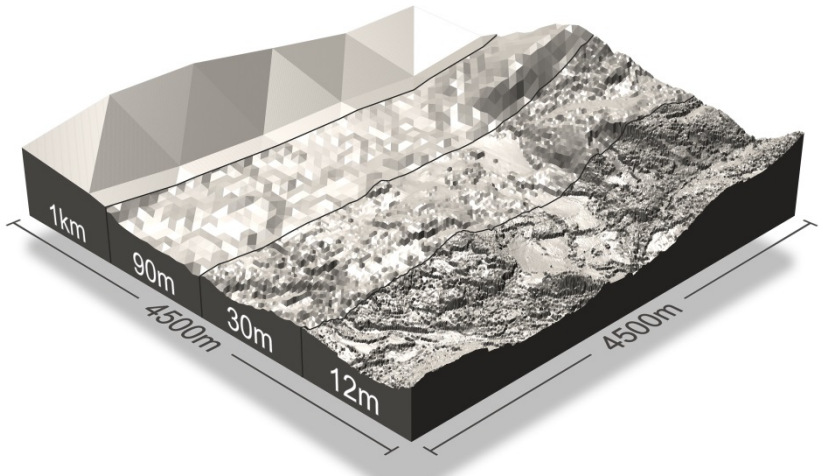
A Space Cloud ?

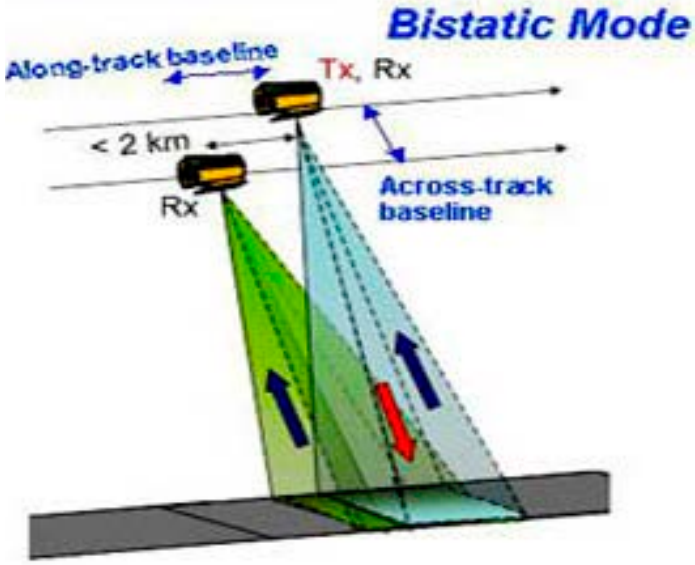
TanDEM-X Earth Observation in 3D

- Synthetic Aperture Radar (SAR)
- Digital Elevation Model of Earth
- 1 Sender / 2 Receivers
- Data Processing on the ground
- 1.5 Petabyte over 3 years





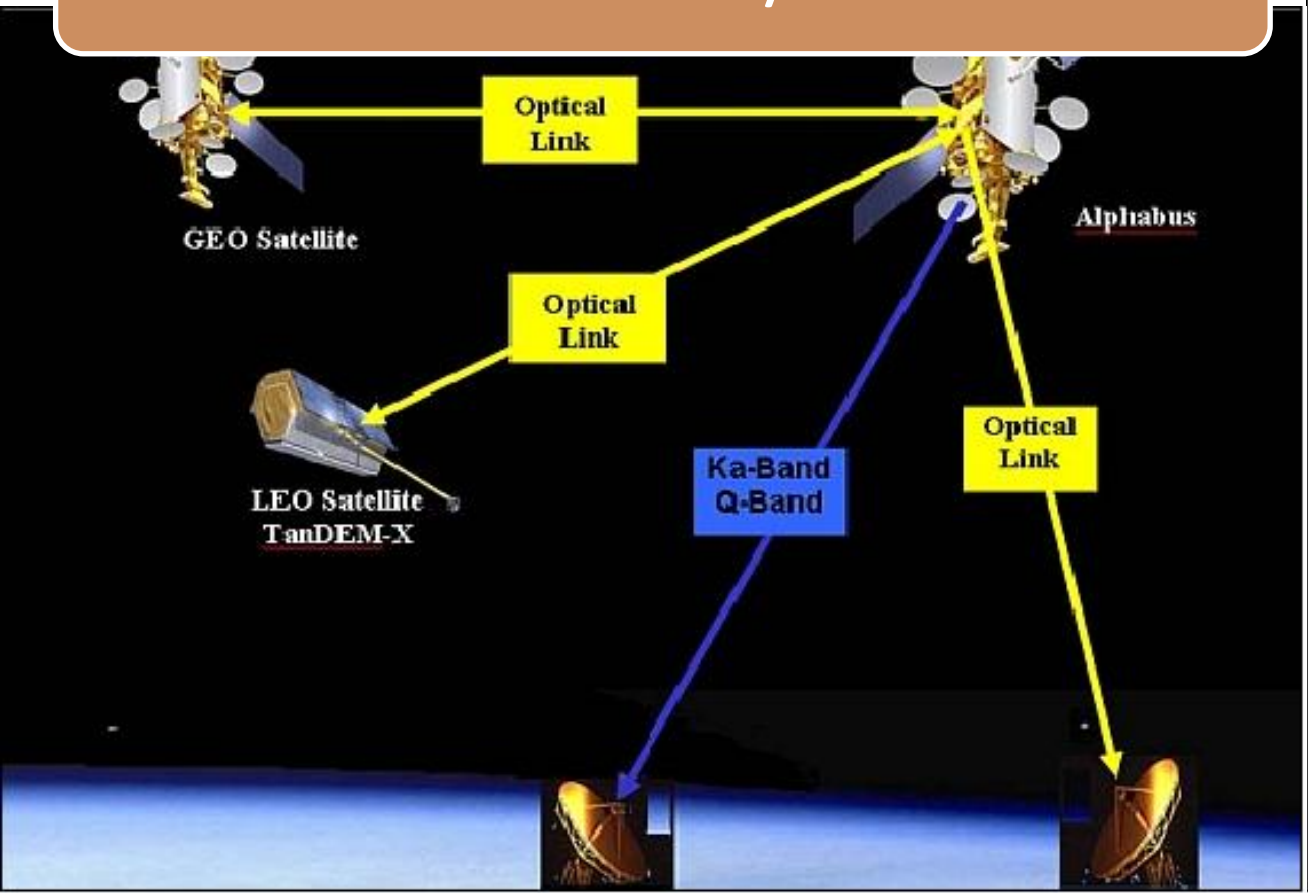


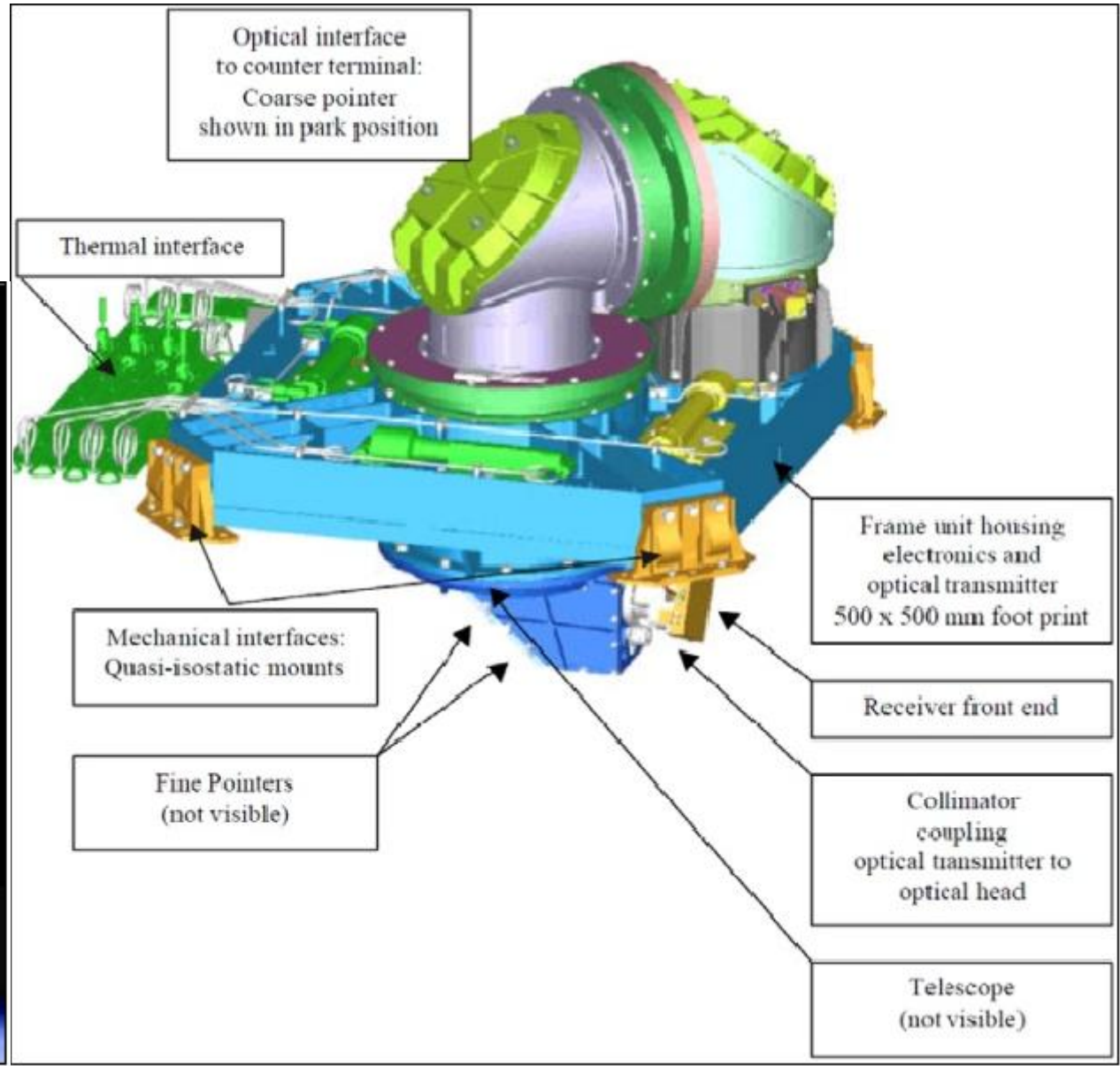


Tandem-X continued: Laser Communication Terminal

Between TerraSAR-X and NFIRE

5000 km – 5.5 Gbit/s





European Data Relay System (EDRS)

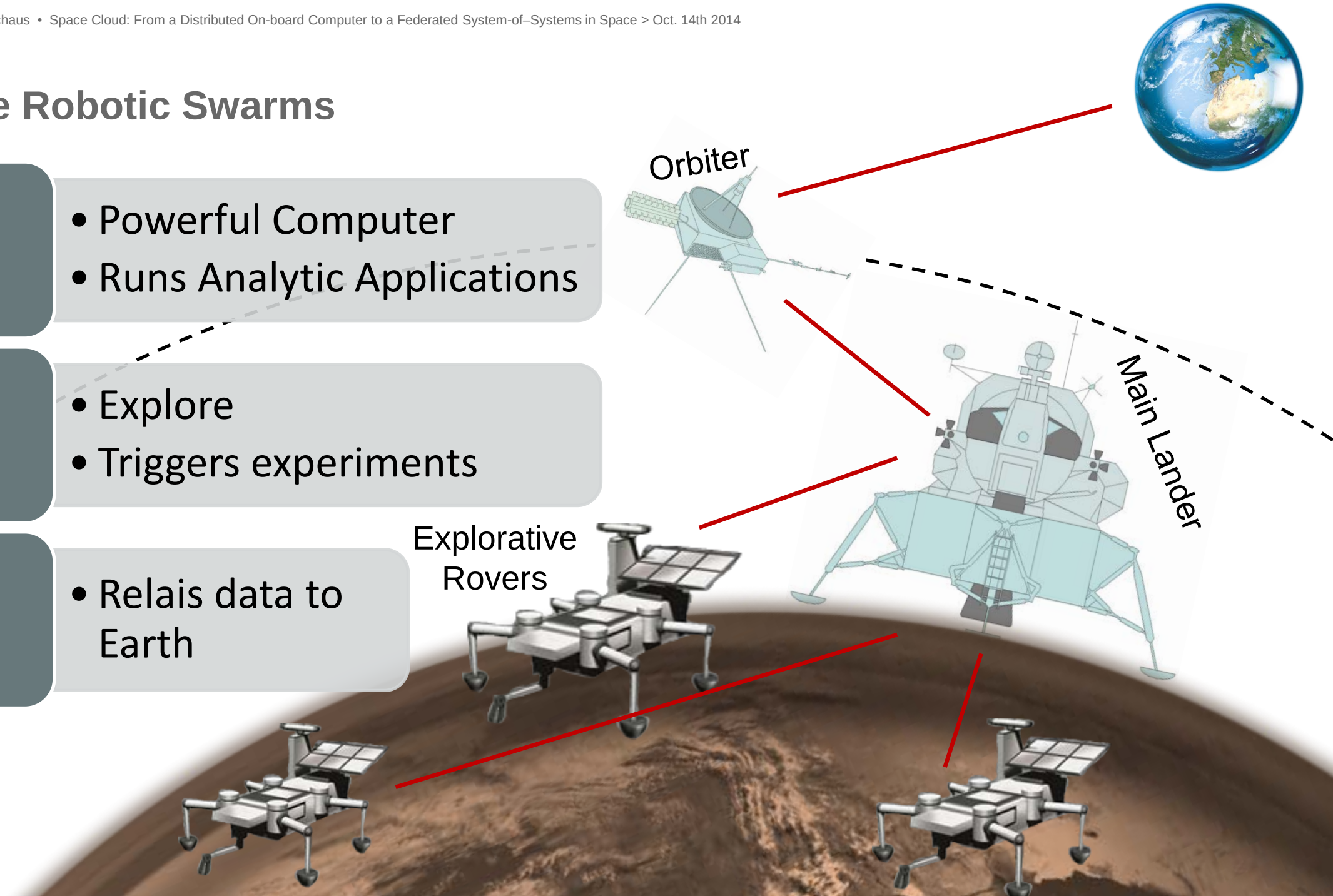
- Geostationary Relais Network
- On-board Alphasat / Sentinel
- 45 000 km – 1.8 Gbit/s
- High Precision Star Tracker
- Cheaper LEO Missions
- Service Architecture in Space

Explorative Robotic Swarms

Main Lander
- Powerful Computer
- Runs Analytic Applications

Rovers
- Explore
- Triggers experiments

Orbiter
- Relais data to Earth



Service Network in Space

Growing Computational Demands

Reconfiguration

Federated Systems

OBC-NG

Distributed Architecture

Explorative Swarm

New Concepts for Onboard Architectures

Redundancy

Resource Sharing

Most Recent Publication:
OBC-NG: Towards a reconfigurable on-board computing architecture for spacecraft
IEEE Aerospace Conference 2014
http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6836179

SpaceBot Cup 2015

Test-bed for new robotic developments

Challenging student teams